Memoirs of the Museum of Victoria 56(2):421–430 (1997)

CONSERVATION STATUS, THREATS AND HABITAT REQUIREMENTS OF AUSTRALIAN TERRESTRIAL AND FRESHWATER MOLLUSCA

WINSTON F. PONDER

Division of Invertebrate Zoology, Australian Museum, 6 College Street, Sydney, NSW 2000, Australia

Abstract

Ponder, W.F., 1997. Conservation status, threats and habitat requirements of Australian terrestrial and freshwater molluscs. *Memoirs of the Museum of Victoria* 56(2): 421–430.

World-wide, non-marine molluscs have the largest number of documented extinctions, and of IUCN — listed threatened species, of any major group. Despite this, as with other invertebrate groups, they attract little or no attention from organisations and government departments concerned with conservation.

Major impediments to the conservation of non-marine molluscs in Australia, and elsewhere, include the lack of appropriate legislation, lack of concordance with existing protected areas and little public and political interest. An Action Plan for Australian molluscs is being prepared as part of an Action Plan for non-marine molluscs world-wide being coordinated through the Mollusc Specialist Group of IUCN. The plan will bring otherwise inaccessible data to public attention and its recommendations will have application in the conservation of non-marine invertebrates in general.

Many Australian non-marine molluscs have very small ranges and are therefore vulnerable to a wide range of threatening processes. The Australian non-marine molluscan fauna currently comprises 1020 named species-group taxa, 80.2% of which are endemic to one State or Territory. 255 species-group taxa (25% of the total fauna) are currently listed by IUCN as threatened in Australia.

Introduction

Invertebrates comprise a large proportion of biodiversity but are very rarely considered in reserve selection and other conservation initiatives in Australia (e.g., Yen and Butcher, 1992; Ponder, 1992a; New, 1995). A major impediment in utilizing invertebrates is that many groups are poorly known both taxonomically and biologically and few people have the expertise to accurately identify them. In addition, unlike the situation with vertebrates and higher plants, funding has not generally been made available to place important collections on data bases. Some of the better known groups, including some insect groups (e.g. butterflies), are known to contain rare and threatened species. However many of these taxa, like many threatened vertebrates and higher plants, have considerable distributional ranges. By way of contrast, some invertebrates, including certain groups of insects and spiders show marked regional endemicity. This is especially true in land and freshwater molluscs and some aquatic crustacean groups, many of which have very restricted ranges (often less than 2 km^2 — e.g., Solem, 1988). Areas which have a concentration of narrow range endemics ('hot-spots') should have a high priority for conservation once identified. Such areas are easily missed in a strictly habitat-based approach to conservation.

Non-marine molluscs are one of the best known groups of non-marine invertebrates (see Smith, 1992, for a reasonably up to date listing of named taxa). Non-marine molluscs, as a group, comprise the largest number of recorded extinctions in the last 300 years [284, listed by IUCN (Groombridge, 1993)] — this being far more than combined world-wide bird and mammal extinctions in the same period. To date, mainland Australia has no absolutely confirmed non-marine mollusc extinctions but this will undoubtedly change, given increasing knowledge about the fauna, the large numbers of narrow range endemics and the rapid rate of habitat destruction that will undoubtedly affect a significant number of Australian non-marine molluscs. However, mollusc conservation continues to have a low profile, even in current discussions on invertebrate conservation. For example, in a recent issue of *Victorian Naturalist* (vol. 112, 1995) devoted to invertebrate conservation, molluscs hardly rated a mention.

An important aspect of IUCN conservation strategy is to produce 'action plans' for particular groups. To date (Nov 1995), there has been only one IUCN Action Plan developed for invertebrates, that being for one small group of insects, Swallowtail Butterflies. The Mollusc Specialist Group (one of the IUCN specialist groups) is well advanced in its production of an Action Plan for all non-marine molluscs of the world. A draft Australian plan has been developed as part of this exercise and some of the findings are summarized below.

The Australian non-marine molluscan fauna

The non-marine fauna of Australia, Lord Howe and Norfolk Islands was catalogued by Smith (1992) who recognised 190 freshwater and 920 terrestrial species, including 52 introduced taxa. On the Australian mainland (including Tasmania), only 14 (1.4%) of the native land and freshwater taxa occur naturally outside Australia, thus the molluscan fauna has a very high endemicity even by Australian standards (98.6% compared with mammals 82%; birds 45%; reptiles 89% and vascular plants 85%). The land and freshwater molluscan fauna of Lord Howe Island (69 terrestrial, 16 freshwater species-group taxa) and Norfolk Islands (68 terrestrial and 1 freshwater) is also almost entirely endemic to each island. Since Smith (1992) an additional 119 species-group taxa have been named (to Jun 1995) (Table 1). Smith (1992) estimated that 30–40% of the non-marine fauna remained to be described, but a more likely estimate is that the total non-marine fauna is around 2000 species.

There are 178 species of Australian (excluding Lord Howe and Norfolk Islands) freshwater molluscs recorded by Smith (1992) and 743 species of terrestrial molluscs. Since then (to late 1995) 119 additional species-group taxa [66 freshwater (representing a 37% increase) and 53 terrestrial (7% increase)] have been described bringing the totals to 244 and 796 respectively and the overall total of named terrestrial and freshwater taxa 1170. Of these 72.1% of the named freshwater fauna (176 species-group taxa) and 69.3% of the named terrestrial fauna (642 species group taxa) are restricted to a single state or territory. Only 14 (1.5%) of these species also occur outside Australia.

For most groups, the work to date has only been descriptive. There are no substantive reviews of most families, and very few phylogenetic treatments. Only two cladistic analyses of non-marine groups have been published, both involving Hydrobiidae (Ponder and Clark, 1990; Ponder et al., 1993). Very little biological information is available, even for common taxa and few detailed distributions have been published.

Terrestrial molluscan fauna

Of the 23 families recognised in the described Australian terrestrial mollusc fauna, the medium to large-sized Camaenidae is by far the most speciose family, with 408 currently valid, named species-group taxa comprising 51.3% of the named terrestrial land snails. The small-sized Charopidae are next (129 named, valid species-group taxa) with 16.2% of the named native terrestrial fauna. Both of these groups, and some other families, contain a large number of unnamed taxa (e.g. Solem, 1991; Stanisic, 1994). In all, nearly half (48%) of the land molluscs of eastern Australia are unnamed (Stanisic, 1994). Other large families include Pupillidae (41 taxa), Bulimulidae (31 taxa), Punctidae (23 taxa), Pupinidae (19 taxa) and Helicarionidae (60 taxa).

Smith (1992) lists 69 native terrestrial molluscs in 10 families on Lord Howe Island. The most diverse are the Helicarionidae (18 species-group taxa), Charopidae (17 species-group taxa),

Table 1. Species-group taxa of Australian freshwater and terrestrial molluscs listed by Smith (1992) with the number of species-group taxa named since added to the totals in brackets. The number in square brackets is the number of species-group taxa restricted to the state or territory, those in the totals columns being the sum of these numbers.

	NSW	Qld	Vic.	SA	WA	NT	Tas.	Total Aus.
Freshwater	42 [11]	56(58) [24]	37(45) [16]	34 [11]	31 [20]	27 [8]	42(98) [86]	178(244) [176]
Terrestrial	140 [79]	234(236) [172]	50 [20]	72(99) [83]	226(230) [201]	71(94) [52]	44 [35]	743(796) [642]
Total	182 [90]	290(294) [196]	87(95) [36]	106(133) [94]	258(262) [221]	98(121) [60]	86(141) [121]	901(1020) [818]

Diplomatinidae (14 species-group taxa) and Punctidae (11 species, with several undescribed, Climo, 1981). The last comprehensive review of the Lord Howe terrestrial molluscan fauna was by Iredale (1944 — see also Stanisic, 1981).

Freshwater molluscan fauna

Australia does not possess a spectacularly diverse freshwater molluscan fauna, having only 18 species of freshwater mussels (Unionoidea: Hyriidae) and very few large-sized gastropods. Apart from the hyriids, corbiculids (2 species) and small numbers of viviparids (6 species) and thiarids (9 species), most of the rest of the fauna (9 families) are of small size. Amongst these, the hydrobiids stand out as being particularly diverse (117 named species-group taxa), many with very restricted distributions (Ponder, 1994) and many remain undescribed. The next largest family, the Planorbidae, has about 40 species. Most families require major revision and more new taxa are known in Assimineidae, Bithyniidae and Glacidorbidae than are currently described. Although the Sphaeriidae was relatively recently revised (Kuiper, 1983), further work on this group is also needed.

For an oceanic island, Lord Howe Island has an exceptional freshwater molluscan fauna. Apart from one record of an ancylid (Ponder, 1981a), there is a remarkable hydrobiid fauna (Ponder, 1982) comprising 15 named species-group taxa in three genera. *Hemistomia minutissima* and another unnamed species live interstitially in sediments in stream beds.

Threatened taxa

Although 255 threatened Australian taxa are listed in the 1994 Red List (Groombridge, 1993) more will be added as details of their distributions and status become available. Other species belong in groups which require taxonomic revision but by far the largest group of unlisted taxa are species which await description. Many undescribed, narrow range camaenids are known, especially from Western Australia, the Northern Territory and Queensland. Charopids are speciose in eastern Australia and many undescribed species have very limited ranges, especially those on limestone outcrops. At present the following numbers of threatened taxa are listed by IUCN (Groombridge, 1993) for each state and territory (T=terrestrial, FW=freshwater) — NSW (mainland 18T, 1FW; Lord Howe Island 4T, 8FW), Queensland (26T, 13FW), Victoria (13T, 5FW), South Australia (19T, 9FW), Western Australia (63T, 1FW), Northern Territory (21T), Tasmania (7T, 60FW) and Norfolk Island (2T, 1FW).

The current listing of only 6 terrestrial species from both Lord Howe and Norfolk islands does not reflect the true nature of the situation. For example *Placostylus bivaricosus* from Lord Howe is certainly threatened, being restricted to a few very small colonies which suffer high levels of rat predation. Data is urgently needed on the current distributions and status of terrestrial taxa on both islands.

Extinctions

Many of the recorded extinctions of terrestrial molluscs are those on oceanic islands. There have been some extinctions of large land snails on Lord Howe Island, probably mostly due to rats (Smithers et al., 1977) and, possibly, pigs, rather than habitat destruction. A large species, *Epiglypta howinsulae* (Cox), is almost certainly extinct, as is a 'form' (or 'subspecies') of *Placostylus bivaricosus* (Gaskoin), *P. bivaricosus etheridgei* (Hedley), both of which occurred on the well forested southern part of the island. Habitat destruction caused by introduced animals was probably responsible for the extinction of another 'form' of *Placostylus, P. cuniculinsulae,* from Rabbit Island (Smithers et al., 1977; Hutton, 1986), as well as other supposed endemic land snails from that island (see Iredale, 1944).

On Norfolk Island, the only recorded freshwater mollusc, the hydrobiid *Posticobia norfolkensis* (Sykes), is now presumed to be extinct (Ponder, 1981b). The environmental degradation of this island and the introduction of feral animals which has resulted in the extinction of several birds and plants has probably affected the terrestrial land snail fauna. Iredale (1945) records the extinction of the land snails of the nearby Phillip Island (3 species) which was completely stripped of vegetation by feral animals by the 1940s and at least 4 species of land snails are now presumed extinct on Norfolk Island itself (R.V.J. Varman, *in litt.*).

There are no published records of confirmed extinctions of non-marine molluscs on the Australian mainland to date. However, this is probably in part because there was a general lack of systematic and/or well documented early collecting of many of the areas now entirely rural and urban. It is probably also a reflection of the poor state of the taxonomy of many of the groups, particularly the lack of modern comprehensive reviews and revisions resulting in poor information on the current status of many species.

Given the considerable localization and high vulnerability in permanent, mainly lowland streams, many hydrobiids have undoubtedly become extinct in the last 200+ years in areas where this family is known to be diverse (e.g. north coast of Tasmania). The detailed work of Ponder et al. (1993) enables the reporting of at least four suspected extinctions of Tasmanian hydrobiids. *Beddomeia tumida* from Great Lake has not been found since the flooding of that lake in the 1920s. An unnamed species of *Beddomeia* with a distinctive shell morphology from 'Table Cape' collected prior to 1900 was not located in a search of virtually all the streams in this heavily impacted area in 1989. An undescribed species of *Phrantela* was collected from the Serpentine River, SW Tasmania prior to the flooding of this area as part of the new Lake Pedder in 1972. This species has not been found in any of the extant streams and rivers in the area. A population attributed to *Beddomeia lodderae* by Petterd (1889) from Deep Creek, Duck River, but which probably represents a distinct species, cannot now be located (Ponder et al., 1993: 603), this area having been cleared for agriculture.

Drawdown from extraction of artesian water since the turn of the century has resulted in the extinction of many of the artesian (mound) springs associated with the Great Artesian Basin (Habermehl, 1982; Ponder, 1986). Given that the considerable endemic aquatic invertebrate faunas associated with these springs (Ponder, 1986) were not recorded until the 1980s, there have probably also been extinctions of significant undocumented faunas.

Near extinctions of viviparids have been reported in the Murray River, with the only surviving population of one species living in a few irrigation pipelines (Sheldon and Walker, 1993a,b). Another species, extinct in the Murray, is known from a few additional populations. At the time of writing the viviparid in the pipelines are in imminent danger of being exterminated because they pose a nuisance through clogging the spray nozzles (K. Walker, *pers. comm.*).

About two thirds of Australia's rainforests have been cleared in the last 200 years but the first detailed survey for molluscs in east coast rainforests was undertaken in 1975 in mid-east Queensland. Of the 92 species collected in only 10 sites, 42% were undescribed (Colman and Burch, 1977).

Limestone areas in particular, because of their often highly localised cave and surface faunas, are particularly vulnerable. In the main, these habitats have only begun to be systematically collected in the last 10 years by J. Stanisic. Clearing of trees from limestone areas for rural activities has probably had a serious impact in some areas, as have mining activities.

Forty-five introduced taxa (Smith, 1992) make up 5.1% of the Australian mainland fauna. There are 13 families of terrestrial molluscs and one freshwater family introduced to Australia, the majority of these taxa being found in rural and urban areas, mainly in the southern, south-eastern and south-western coastal areas and Tasmania (Smith, 1981, 1992; Kershaw, 1991). Some helicids (see Smith and Kershaw, 1981; Baker, 1989) and limacid slugs (see Altena and Smith, 1975) are economic pests. Nothing is known about the interactions between native and introduced taxa.

Habitat conservation

The belief that habitats conserved for other organisms (namely vertebrates and higher plants), or on a representative ecosystem basis, will provide effective conservation for invertebrates is well entrenched. Whereas this may be effective for many widely distributed species (which are typically at low risk) it is generally inappropriate for many of the taxa of high conservation significance such as narrow range endemics, including many relict taxa. However, there are some areas where general conservation interests and those of molluscan conservation coincide, either because of general concerns for important habitats such as rainforests, or because of happy accidents, where areas set aside for conservation include areas that are important for narrow range endemic invertebrate taxa, typically without this having being realised (e.g., limestone cave reserves).

The conservation of rainforests is critical for molluscan conservation. They occupy only about 4.5% of Australian forests but contain a large proportion of the molluscan taxa. Existing rainforests are essentially refugia, occupying only about 20,000 km^2, mainly along the east coast of Australia (Webb and Tracey, 1981) with a few small areas of monsoonal rainforest patches from Cape York Peninsula in the north east to the Kimberley in the north west. Much of the lowland rainforest has been cleared for agriculture. Rainforest remnants are still being cleared and are sometimes considered of little or no conservation value if they are of insufficient size to maintain large vertebrates. However, such areas may be vital for the continuing existence of locally endemic invertebrates, small plants and even small vertebrates (e.g., Meave et al., 1991).

The tropical rainforests of NE Queensland are a very important habitat for land snails (Stanisic, 1994) some locations with in excess of 40 species of land molluscs. Dry rainforest (vine thickets) inland from the coast in Queensland have reduced diversity (averaging about 10 species) although inland areas of moist refugia or limestone have higher diversities (Stanisic, 1994). The subtropical rainforests of south east Queensland and New South Wales also contain diverse molluscan faunas (Colman and Burch, 1977; Stanisic, 1994). Although generally a lower diversity than those further north (Stanisic, 1994), areas associated with limestones in the Macleay Valley peak in diversity at 36 species but in most sites in northern NSW 10–20 species is usual (Stanisic, 1994). There are few locations in the world in which the land mollusc diversity exceeds 30 species (Solem, 1984b). Monsoonal rainforests occur in small patches across northern Australia and are mostly poorly documented for molluscs but the Kimberley rainforest patches have been surveyed in some detail (McKenzie et al., 1991). These contain a rich molluscan fauna (Solem, 1991; Solem and McKenzie, 1991) with 115 species, all but 22 being camaenids. There is an average 12.5 species (average 3.7 species of camaenids) per rainforest patch (size <1 ha to >20), the mean species range for camaenids was about 20 km in diameter and about 64% of camaenids were recorded from only one or two patches. Temperate rainforests, typically dominated by *Nothofagus*, are found in Victoria and Tasmania, although the great majority (456,000 ha) is in Tasmania. These forests also contain a distinctive fauna, but it is less diverse than that seen in northern rainforests.

The remaining 95.5% of Australian forests are mainly dry forests, much of this dominated by eucalypts (about 67.4%). Such forests are generally poor habitats for terrestrial molluscs, although wet sclerophyll (mixed eucalypt and rainforest species) can contain diverse faunas. Rainfall can be high in some areas with eucalypt forests but even in these areas molluscan faunas are typically sparse, probably because of generally low water retention in soils and regular fires. However, dry forests can be important habitats when local topography or geology results in establishing suitable conditions for refugia.

Other terrestrial areas of high conservation value are largely circumscribed by geomorphological features resulting in their being very long-term suitable habitats. Of particular importance are limestone outcrops in which endemicity of terrestrial species is usually very high. This is especially true in eastern Queensland and New South Wales (Stanisic, 1994) and in north Western Australia (Solem, 1981a,b, 1984a, 1985, 1988, 1991). When limestone areas occur in rainforests diversity is particularly high (Stanisic, 1994). Limestone habitats are often protected, at least in part, if they are associated with caves. However, many other outcrops are not protected and are often cleared or mined.

Arid zone refugia, particularly deep gorges, can be very important, especially if associated with limestone. There is a rich camaenid fauna in the Kimberley (Solem, 1981a,b, 1984a, 1985, 1988, 1991), Flinders Ranges (Solem, 1992a,b), and the gorges of the Red Centre (Solem, 1993), and even the coastal areas along the Great Australian Bight have a few endemic species (Solem, 1992a,b). In an important review of arid zone refugia (Morton et al., 1995), published data on terrestrial and aquatic molluscs were taken into account. However, when assessing the relative conservation importance of particular habitats only threatened vertebrates (ANZECC listed species) were considered.

The conservation of Australian aquatic habitats is reviewed by Lake (1980) and McComb and Lake (1988). The only national review of the conservation of Australian inland aquatic fauna is that of Michaelis (1986), but few molluscs were noted. Most Australian lakes are very recent and do not contain endemic molluscan faunas. A few Tasmanian lakes, particularly Lake Sorell, Lake Crescent and Great Lake are older and contain a few endemics (Fulton, 1983), including some molluscan taxa. The few large rivers in Australia have a rather low diversity of freshwater molluscs when compared with some rivers in south east Asia and North America. The most conspicuous of the freshwater molluscs, the hyriids, are typically widely distributed, although *Hyridella glenelgensis* (south western Victoria) and *H. moretonicus* (Tasmania) are exceptions (McMichael and Hiscock, 1958).

Small streams and, to a lesser extent, local ground-water seepages and springs, are the major habitats of the majority of hydrobiid there is virtually no information on the biology and ecology of most Australian non-marine molluscs. Such basic data gathering is vital to our understanding of how we might best facilitate the long term survival of many taxa. Coupled with this, work on the threats to native molluscs needs to be encouraged and facilitated. For example, there is virtually no data on the long term affects of fire, damming, salination and pollution on Australian molluscs.

Acknowlegements

I thank Ian Loch, Greg Shirley and Alison Miller for comments on the manuscript. The data for the 1994 IUCN listings was provided by several colleagues, mainly Vince Kessner, Brian Smith, Shirley Slack-Smith, John Stanisic, Phil Colman and Bronwyn Scott.

References

Altena, C.O. van R. and Smith, B.J., 1975. Notes on introduced slugs of the families Limacidae and Milacidae in Australia, with two new records. *Journal of the Malacological Society of Australia* 3: 63–80.

Baker, G.H., 1989. Damage, population dynamics, movement and control of pest helicid snails in southern Australia. pp. 175–185 *in* Henderson, I. (ed.) *BCPC Monogr. No. 41. Slugs and Snails in World Agriculture.*

Butcher, R.J., P.E. Clunie, and A.L. Yen, 1994. The Victorian *Flora and Fauna Guarantee Act:* flagship legislation for invertebrate conservation. *Memoirs of the Queensland Museum* 36: 13–19.

Butcher, R. and T.J. Doeg, 1995. Conservation of freshwater invertebrates. *Victorian Naturalist* 112: 15–19.

Campbell, I.C. and T.J. Doeg, 1989. Impact of timber harvesting and production on streams: a review. *Australian Journal of Marine and Freshwater Research* 40: 519–539.

Climo, F.M., 1981. Punctidae — minute land snails. P. 11 in: Recher, H.F. and Ponder, W.F., (eds), Lord Howe Island, a summary of current and projected scientific and environmental activities. *Occassional Reports of the Australian Museum* 1.

Colman, P.H. and Burch, J.B., 1977. Molluscs. Pp. 54–58 in: Goldstein, W. (ed.), *Rainforests.* Reprinted from Parks and Wildlife. 2(1). National Parks and Wildlife Service, NSW.

Cooling, M.P. and Boulton, A.J., 1993. Aspects of the hyporheic zone below the terminus of a South Australian arid-zone stream. *Australian Journal of Marine and Freshwater Research* 44: 411–426.

Daniell, A., 1994. Genetics and terrestrial mollusc conservation. *Memoirs of the Queensland Museum* 36: 47–53.

DEST, 1994. *Australia's biodiversity, an overview of selected significant components.* Biodiversity Series, Paper 2, Biodiversity Unit, Department of the Environment, Sport and Territories: Canberra. 87 pp.

Evans, J.W., 1942. *The food of trout in Tasmania.* Salmon and Freshwater Fisheries Commission, Hobart.

Fulton, W., 1983. Macrobenthic fauna of Great Lake, Arthurs Lake and Lake Sorell, Tasmania. *Australian Journal of Marine and Freshwater Research* 34: 775–785.

Groombridge, B. (ed.), 1993. *1994 IUCN Red List of threatened animals.* IUCN, Gland,. Switzerland and Cambridge, UK. lvi +286 pp.

Habermehl, M.A., 1982. *Springs in the Great Artesian Basin, Australia — their origin and nature.* Australian Bureau of Mineral Resources, Geology and Geophysics, Report No. 235.

Hart, B., 1993. A national approach to river management. *Search* 24: 125–130.

Hill, A., Johnson, M.S. and Merrifield, H., 1983. An electrophoretic and morphological examination of *Bothriembrion kendricki* (Pulmonata: Bulimulidae), a new species previously considered conspecific with *B. bulla* (Menke). *Australian Journal of Zoology* 31: 227–242.

Hutton, I., 1986. *Lord Howe Island.* Conservation Press: Canberra. 157 pp.

Invertebrate Advisory Committee, 1994. *Interim list of native invertebrates which are threatened or rare in Tasmania.* Parks and Wildlife Service: Hobart. 44 pp.

Iredale, T., 1944. The land Mollusca of Lord Howe Island. *Australian Zoologist* 10: 299–334.

Iredale, T., 1945. The land Mollusca of Norfolk Island. *Australian Zoologist* 11: 46–71.

Jackson, P.D., 1981. Trout introduced into south-eastern Australia: their interaction with native fishes. *Victorian Naturalist* 98: 18–24.

Kershaw, R.C., 1991. *Snails and slugs introduced to or pests in Tasmania.* Queen Victoria Museum and Art Gallery. Launceston. 67 pp.

Kuiper, J.G.J., 1983. The Sphaeriidae of Australia. *Basteria* 47: 3–52.

Lake, P.S., 1980. Conservation. Pp. 163–173 in: Williams, W.D. (ed.), *An ecological basis for water resource management.* Australian National University Press: Canberra.

Martin, P., and Lockie, S., 1993. Environmental information for total catchment management: incorporating local knowledge. *Australian Geographer* 24: 75–85.

McComb, A.J., and Lake, P.S. (eds), 1988. *The conservation of Australian wetlands.* Surrey Beatty and Sons: Chipping Norton. 196 pp.

McKenzie, N.L., Johnston, R.B. and Kendrick, P. G. (eds), 1991. *Kimberley rainforests of Australia.* Surrey Beatty and Sons: Chipping Norton. xiv + 490 pp.

McMichael, D.F., and Hiscock, I.D., 1958. A monograph of the freshwater mussels (Mollusca: Pelecypoda) of the Australian region. *Australian Journal of Marine and Freshwater Research* 9: 372–508.

Meave, J., Kellman, M., McDougall, A. and Rosales, J., 1991. Riparian habitats as tropical forest refugia. *Global Ecology and Biogeography Letters* 1: 69–76.

Michaelis, F.B., 1984. Possible effects of forestry on inland waters of Tasmania: a review. *Environmental Conservation* 11: 331–344.

Michaelis, F.B., 1986. Conservation of Australian aquatic fauna. Pp. 599–613 in: DeDeckker, P. and Williams, W.D. (eds), *Limnology in Australia*. CSIRO: Melbourne.

Morton, S.R., Short, J. and Barker, R.D., 1995. *Refugia for biological diversity in arid and semi-arid Australia*. Biodiversity Series, Paper 4, Biodiversity Unit, Department of Environment, Sport and Territories. 171 pp.

New, T.R., 1995. *Introduction to invertebrate conservation biology*. Oxford University Press: Oxford. xxi + 194 pp.

Norris, R.H., Lake, P.S. and Swan, R., 1982. Ecological effects of mine effluents on the South Esk River, North-eastern Tasmania III. Benthic macroinvertebrates. *Australian Journal of Marine and Freshwater Research* 33: 789–809.

Petterd, W.F., 1889. Contributions for a systematic catalogue of the aquatic shells of Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 1888: 60–82, pls 1–4.

Pollard, D.A., and Burchmore, J.J., 1986. A possible scenario for the future of Australia's freshwater fish fauna. Pp. 615–636 in: DeDeckker, P. and Williams, W.D. (eds), *Limnology in Australia*. CSIRO: Melbourne.

Ponder, W.F., 1981a. Freshwater snails. P. 11 in: Recher, H.F. and Ponder, W.F. (eds), Lord Howe Island, a summary of current and projected scientific and environmental activities. *Occassional Reports of the Australian Museum* 1.

Ponder, W.F., 1981b. *Posticobia norfolkensis* (Sykes), an apparently-extinct, freshwater snail from Norfolk Island (Gastropoda: Hydrobiidae). *Proceedings of the Linnean Society of NSW* 105: 17–21.

Ponder, W.F., 1982. Hydrobiidae of Lord Howe Island (Mollusca: Gastropoda: Prosobracnhia). *Australian Journal of Marine and Freshwater Research* 33:89–159.

Ponder, W.F., 1986. Mound springs of the Great Artesian Basin. Pp. 403–420 in: DeDeckker, P. and Williams, W.D. (eds), *Limnology in Australia*. CSIRO: Melbourne.

Ponder, W.F., 1992a. Bias and biodiversity. *Australian Zoologist* 28: 47–51.

Ponder, W.F., 1992b. A new genus and species of aquatic cave-living snail from Tasmania (Mollusca: Gastropoda: Hydrobiidae). *Papers and Proceedings of the Royal Society of Tasmania* 126: 23–28.

Ponder, W.F., 1994. Australian freshwater Mollusca: Conservation priorities and indicator species. *Memoirs of the Queensland Museum* 36: 191–196.

Ponder, W.F. and Clark, G.A., 1990. A radiation of hydrobiid snails in threatened artesian springs in western Queensland. *Records of the Australian Museum* 42: 301–363.

Ponder, W.F., Clark, G.A., Miller, A.C. and Toluzzi. A., 1993. On a major radiation of freshwater snails in Tasmania and eastern Victoria: A preliminary overview of the *Beddomeia* group (Mollusca: Gastropoda: Hydrobiidae). *Invertebrate Taxonomy* 7: 501–750.

Ponder, W.F., Colgan, D.J., Clark, G.A., Miller, A.C. and Terzis, T., 1994. Microgeographic, genetic and geographical differentiation of freshwater snails — the Hydrobiidae of Wilsons Promontory, Victoria, south eastern Australia. *Australian Journal of Zoology* 42: 557–678.

Ponder, W.F., Colgan, D.J., Terzis, T., Clark, S.A. and Miller, A.C., 1996. Three new morphologically and genetically determined species of hydrobiid gastropods from Dalhousie Springs, northern South Australia, with the description of a new genus. *Molluscan Research*, 17: 49–109.

Ponder, W.F., Eggler, P. and Colgan, D.J., 1995. Genetic differentiation of aquatic snails (Gastropoda: Hydrobiidae) from artesian springs in arid Australia. *Biological Journal of the Linnean Society* 56: 553–596.

Ponder, W.F., Hershler, R. and Jenkins, B., 1989. An endemic radiation of hydrobiid snails from artesian springs in northern South Australia: their taxonomy, physiology, distribution and anatomy. *Malacologia* 31: 1–140.

Ridge, S., 1995. *A study of how environmental parameters impinge on the disturbance and abundance of freshwater molluscs in the coastal drainages between Jervis Bay and Sydney*. Honours Thesis, University of Wollongong.

Sheldon, F. and Walker, K.F., 1993a. Pipelines as a refuge for freshwater snails. *Regulated Rivers: Research and Management* 8: 295–299.

Sheldon, F. and Walker, K.F., 1993b. Shell variation in Australian *Notopala* (Gastropoda: Prosobranchia: Viviparidae). *Journal of the Malacological Society of Australia* 1993: 59–71.

Smith, B.J., 1981. Introduced non-marine molluscs in Australia. *Victorian Naturalist* 98: 24–27.

Smith, B.J., 1992. Non-marine Mollusca. *Zoological Catalogue of Australia* 8: 1–398.

Smith, B.J., and Kershaw, R.C., 1979. *A field guide to the non-marine molluscs of south eastern Australia*. Australian National University Press: Canberra. x +285 pp.

Smith, B.J. and Kershaw, R.C., 1981. *Tasmanian land and freshwater molluscs*. Fauna of Tasmania Handbook, 5. 148 pp.

Smithers, C., McAlpine, D., Colman, P. and Gray, M., 1977. *Island invertebrates. Lord Howe Island.* Australian Museum: Sydney.

Solem, A., 1981a. Camaenid land snails from Western and central Australia (Mollusca: Pulmonata: Camaenidae). II. Taxa from the Kimberley, *Amplirhagada* Iredale, 1933. *Records of the Western Australian Museum, Supplement* 11: 147–320.

Solem, A., 1981b. Camaenid land snails from Western and central Australia (Mollusca: Pulmonata: Camaenidae). III. Taxa from Ningbing Ranges and nearby areas. *Records of the Western Australian Museum, Supplement* 17: 427–705.

Solem, A., 1984a. Camaenid land snails from Western and central Australia (Mollusca: Pulmonata: Camaenidae). IV. Taxa from the Kimberley, *Westraltrachia* Iredale, 1933. *Records of the Western Australian Museum, Supplement* 11: 147–320.

Solem, A., 1984b. A world model of land snail diversity and abundance. Pp. 6–22 in: Solem, A. and Van Bruggen, A.C. (eds), *World-wide snails.* Biogeographical studies on non-marine Mollusca. E.J. Brill/Dr W. Backhuys, Leiden.

Solem, A., 1985. Camaenid land snails from Western and central Australia (Mollusca: Pulmonata: Camaenidae). V. Remaining Kimberley taxa and addenda to the Kimberley. *Records of the Western Australian Museum, Supplement* 20: 707–981.

Solem, A., 1988. New camaenid land snails from the northeast Kimberley, Western Australia. *Journal of the Malacological Society of Australia* 9: 27–58.

Solem, A., 1991. Land snails of Kimberley rainforest patches and biogeography of all Kimberley land snails. Pp. 145–246 in: McKenzie, N.L., Johnston, R.B. and Kendrick, P.G., (eds), *Kimberley rainforests of Australia.* Surrey Beatty and Sons: Chipping Norton.

Solem, A., 1992a. Camaenid land snails from southern and eastern South Australia, excluding Kangaroo Island. Part 1. Systematics, distribution, and variation. *Records of the South Australian Museum, Monograph Series* 2: 1–338.

Solem, A., 1992b. Camaenid land snails from southern and eastern South Australia, excluding Kangaroo Island. Part 2. Biogeography and covariation. *Records of the South Australian Museum, Monograph Series* 2: 339–395.

Solem, A., 1993. Camaenid land snails from Western and central Australia (Mollusca: Pulmonata: Camaenidae). VI. Taxa from the Red Centre. *Records of the Western Australian Museum, Supplement* 43: 983–1459.

Solem, A. and McKenzie, N.L., 1991. The composition of land snail assemblages in Kimberley rainforests. Pp. 247–263 in: McKenzie, N.L., Johnston, R.B. and Kendrick, P.G., (eds). *Kimberley rainforests of Australia.* Surrey Beatty and Sons: Chipping Norton..

Stanisic, J., 1981. Land Mollusca. Pp. 12–13 in: Recher, H.F. and Ponder, W.F. (eds), Lord Howe Island, a summary of current and projected scientific and environmental activities. *Occassional Reports of the Australian Museum* 1.

Stanisic, J., 1990. Systematics and biogeography of eastern Australian Charopidae (Mollusca, Pulmonata) from subtropical rainforests. *Memoirs of the Queensland Museum* 30: 1–241.

Stanisic, J., 1994. The distribution and patterns of species diversity of land snails in eastern Australia. *Memoirs of the Queensland Museum* 36: 207–214.

Stoddart, J.A., 1983. The accumulation of genetic variation in a parthenogenetic snail. *Evolution* 37: 546–554.

Stoddart, J.A., 1985. Analysis of species lineages of some Australian thiarids (Thiaridae, Prosobranchia, Gastropoda) using the evolutionary species concept. *Journal of the Malacological Society of Australia* 7: 7–16.

Tilzey, R.D.J., 1980. Introduced fish. Pp. 271–279 in: Williams, W.D. (ed), *An ecological basis for water resource management.* Australian National University Press: Canberra.

Walker, K.F., 1985. A review of the ecological effects of river regulation in Australia. *Hydrobiologia* 125: 111–129.

Walker, K.F., Thoms, M.C. and Sheldon, F., 1992. Effects of weirs on the littoral environment of the River Murray, South Australia. Pp. 270–293in: Boon, P.J., Calow, P.A. and Petts G.E. (eds), *River Conservation and Management.* Wiley: Chichester.

Webb, L.J. and Tracey, J.G.,1981. Rainforests: patterns and change. Pp. 606–694 in: Keast, A. (ed), *Ecological biogeography of Australia.* W. Junk, The Hague.

Williams, W.D., 1980. Catchment management. Pp. 100–114 in: Williams, W.D. (ed), *An ecological basis for water resource management.* Australian National University Press: Canberra.

Wilson, J.H., 1966. The food of trout in Great Lake. *Australian Society of Limnology, Newsletter* 5: 21–23.

Woodruff, D.S. and Solem, A., 1990. Allozyme variation in the Australian camaenid land snail *Cristilabrum primum*: a prolegomenon for a molecular phylogeny of an extraordinary radiation in an isolated habitat. *The Veliger* 33: 129–139.

Yen, A.L. and Butcher, R.J., 1992. Practical conservation of non-marine invertebrates. *Search* 23: 103–105.

Memoirs of the Museum of Victoria 56(2):431–433 (1997)

A CONSERVATION PROGRAMME FOR THE PARTULID TREE SNAILS OF THE PACIFIC REGION

PAUL PEARCE-KELLY, DAVE CLARKE, CRAIG WALKER AND PAUL ATKIN

Invertebrate Conservation Centre, Zoological Society of London, Regent's Park, London NW1 4RY, UK

Abstract

Pearce-Kelly, P., Clarke, D., Walker, C. and Atkin, P., 1997. A conservation programme for the partulid tree snails of the Pacific region. *Memoirs of the Museum of Victoria* 56(2): 431–433.

Throughout the Pacific numerous endemic mollusc species have either become extinct in the wild or are currently facing the threat of extinction as a result of introduction of the predatory snail *Euglandina rosea* and the New Guinea flatworm *Platydemus manokwari*. Without determined conservation efforts, including the establishment of *ex situ* breeding programmes, much of the region's endemic snail fauna will be lost. Since 1986 a collaborative international conservation programme has been in place for partulid tree snails. The participating institutions currently maintain a total of 33 taxa in culture (comprising > 12 000 snails). The conservation status of all 117 partulid species has been assessed using the *Conservation Action Management Plan* (CAMP) process. Target *ex situ* population sizes required to maintain 90% of starting heterozygosity over 100 years have been calculated using the analytical model programme CAPACITY (Pearce-Kelly et al., 1994) The genetic management requirements of the breeding programme have necessitated the development of a colony management computer database enabling demographic management and analysis of the populations. The ability of long term captive-bred snails to readapt to natural field conditions was investigated using a trial release and monitoring experiment at Kew Gardens. Field introduction trials via the construction of predator-proof forest reserves, were commenced in 1994.

Introduction

An ill-conceived attempt at biological control of the African land snail *Achatina fulica* (using the snail predator *Euglandina rosea* and the New Guinea flatworm *Platydemus manokwari*) has resulted in large numbers of endemic mollusc species becoming extinct, or facing the threat of extinction, throughout the Pacific region. Without the establishment of *ex situ* breeding programmes many of these endemic species will face extinction.

The 117 species of Polynesian tree snails of the family Partulidae once spread over a wide group of volcanic islands of the west, central and south Pacific. Each island had its own endemic species, which were often further restricted to individual valleys. The product of extraordinary selective pressures, *Partula* (the largest and most studied genus of the Partulidae) has provided researchers with an invaluable insight to the mechanisms behind speciation (Johnson et al., 1995). In addition to their scientific importance many species of Partulidae are valued elements of the region's rich cultural heritage.

The introduction of *Euglandina* has had a disastrous effect on the region's species of Partulidae. *Euglandina* paid scant attention to its intended *Achatina* target preferring to prey on the smaller endemic snails. Extensive field surveys have determined that many partulid species have been preyed to extinction throughout their natural range (Murray and Clarke, 1984; Pearce-Kelly et al., 1994).

In 1986 the international zoo community, in association with IUCN's Captive Breeding Specialist Group, devised an international conservation programme to establish viable *ex situ* populations of as many endangered partulid species as possible. The programme is currently maintaining in culture 33 taxa (totalling >12 000 individuals) in 18 collections in Europe and North America.

A workshop in 1994 used the *Conservation Action Management Plan* (CAMP) process (Seal et al., 1994) to assess the conservation status of every species within the Partulidae. This review determined that no species could be considered as being less than endangered and identified 53 species as being in need of urgent captive-breeding assistance (Pearce-Kelly et al., 1994). Because of the intensive culture requirements associated with the Partulidae, together with the large number of species requiring captive-breeding assistance, the workshop calculated the target population sizes required to maintain 90% of starting heterozygosity over 100 years using the analytical model programme CAPACITY (Flesness and Mace, 1988; Soule et al., 1986) The results of this exercise suggested that a minimum of 250 adults, together with their associated young, need to be maintained for each species in the breeding programme.

The demographic labyrinth

Maintaining healthy genetic populations of any species over successive generations requires a management protocol that takes account of the major factors that lead to loss of genetic diversity. These factors are genetic drift (the random process which results when a limited sample of genes from one generation is transmitted to the next), inbreeding depression (mating between relatives which can result in reduced characters such as fertility and growth rate), artificial selection (the disproportionate survival of individuals adapted to the prevailing environmental conditions — in captivity selective pressures may differ from those in the wild) and disease. In order to balance these considerations the snail cultures are maintained along inbred and outbred lines with genetic drift and inbreeding depression being minimised in the outbred lines while the inbred lines best reduce the risks of selection pressures and disease.

The taxa in the Partulidae programme derive not only from different islands but from different valleys and collection sites within valleys. Each of the >100 collection sites represents a genetically unique population which needs to be maintained as a separate breeding line. The need for generation separation and monitoring of the four developmental stages (defined as new born, juvenile, subadult and adult) are further management complications. These considerations are compounded by the need to maintain populations as colonies of up to 200 snails, of mixed age structure. The development of a computerized colony database (CERCI) has, for the first time, enabled the detailed monitoring and analysis of demographic trends, and environmental and genealogical data in colony populations.

Re-establishment

The effectiveness of the breeding programme in maintaining viable populations was tested in 1994 when a group of zoo-bred *Partula taeniata* was released on to Polynesian plants growing at Kew Gardens. This 16 month trial suggested that long term captive-bred *Partula* populations have retained their ability to readapt to a natural environment and diet (Pearce-Kelly et al., 1995). The latest development has been the commencement of reestablishment on the French Polynesian island of Moorea (Murray, 1995). Because of continued predator threat, this aspect of the programme has involved the construction of a predator-proof reserve, 20 m × 20 m, built with cheap locally available materials, and containing three species of captive-bred *Partula* snails (Murray, 1995).

For the foreseeable future, it is not possible to progress beyond the predator-proof reserve strategy due to the high numbers of surviving *Euglandina* in the habitat. These *Euglandina* are feeding on native micro-snails in the leaf litter and will continue to prevent the full re-establishment of *Partula* into the wild until effective predator control measures are developed.

To ensure that the captive snails do not become diseased, lose their natural resilience to endemic micro-organisms, or introduce alien microbes when returned to their native habitat, an extensive screening exercise is in place to determine the nature and levels of enteric gut fauna and flora in both the wild and captive *Partula* populations.

Other conservation initiatives

Educational material is being produced to help raise public awareness of the ecological disaster facing the indigenous snail fauna throughout the Pacific and, to illustrate how Polynesians can help prevent further extinctions of endemic molluscs, legislation is being formulated to prohibit further introduction of alien species into French Polynesia. These two initiatives are the most effective conservation action that can be taken to reduce the likelihood of alien predators being introduced to islands that have thus far escaped such disastrous importations.

Conclusion

The extinction of endemic species of mollusc throughout the Pacific is continuing. Without concerted *in situ* and *ex situ* action, of the nature outlined above, it can only escalate. The significance for conservation of such action is highlighted by the number of species currently afforded a second chance of survival through captive-breeding programmes. In addition to benefiting the individual target species, such programmes are potential conservation models